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STRENGTH TESTS OF STRUCTURAL TIMBERS TREATED BY COMMERCIAL WOOD-PRESERVING PROCESSES.

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CONTENTS.

OBJECT OF THE TESTS.

This bulletin presents the results of tests made by the Forest Service, in cooperation with the Illinois Central Railway and one eastern and two western wood-preserving companies, to determine how the strength of bridge stringers is affected by commercial creosote treatments. To do this, comparison was made between the strength of treated and untreated stringers of the same size and quality. The test timbers were selected by representatives of the Forest Service from stock furnished by the cooperators. The Forest Service requested that the treatments given the timbers by each of the cooperators be that used in its regular commercial practice. A Forest Service representative was present during the treatments and kept a record of the various conditions to which the material was subjected. The woods used were loblolly pine, longleaf pine, and Douglas fir. After treatment the loblolly and longleaf pine were shipped to the Forest Service timber-testing laboratory at Lafayette, Ind.,[1] and the Douglas fir to the Forest Service timber-testing station, Seattle, Wash.[2]

[1] Formerly conducted in cooperation with Purdue University.
[2] Conducted in cooperation with the University of Washington.

Note.—This report is of interest to users of timber where strength is an important consideration.

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MATERIAL TESTED.

The material for test was selected from regular stock, in the form of sticks 8 inches by 16 inches in section and from 28 to 32 feet in length. The sticks were sorted in pairs, with the object of having those in each pair as alike as possible. At the time of treatment each stick was cut into two stringers of equal length, making four test stringers in each group, two butt cuts and two second or top cuts. The groups were handled as shown in figure 1, the butt ends in one group being treated and the top ends in the next.

LONGLEAF AND LOBLOLLY PINE.

The longleaf and loblolly pine timber were cut in southern Mississippi and Louisiana. About five months elapsed between the time

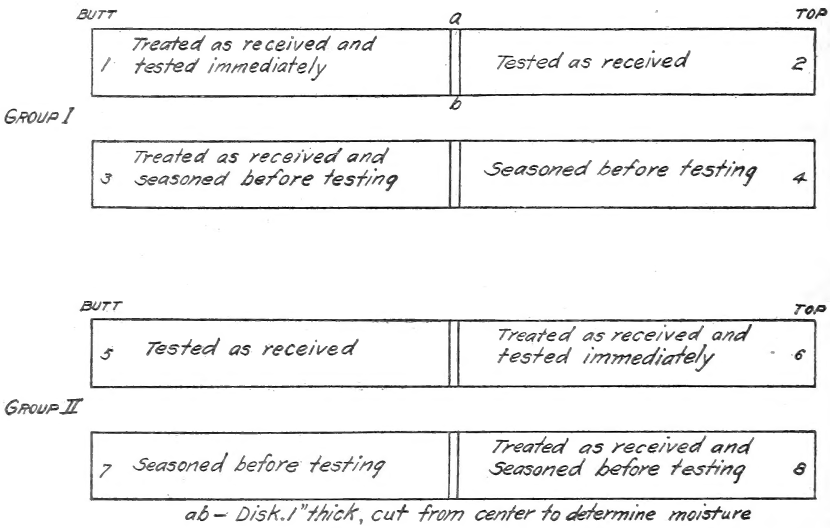

FIG. 1.—Method of cutting and marking test material.

the logs were sawed and the time of treatment, during four months of which the pieces were seasoned in an open pile. The treated stringers were en route to Lafayette, Ind., for over a month. Upon arrival they were close piled under shelter until the tests were started about a month later. The pieces as selected were 8 inches by 16 inches in section by 28 feet long. The material classed as "longleaf" was high-grade timber, considered as first-class structural material by the railway officials, and that classed as "loblolly" as less valuable. The longleaf had only a small per cent of sap and was of comparatively slow growth, while the loblolly averaged over 30 per cent sapwood, was of more rapid growth, and contained more knots. The number of test stringers 14 feet long was as follows:

Longleaf:
- 5 treated partially air dry and tested.
- 5 tested partially air dry.
- 5 treated partially air dry, seasoned, and tested.
- 5 seasoned and tested.

Loblolly:
- 5 treated partially air dry and tested.
- 5 tested partially air dry.
- 5 treated partially air dry, seasoned, and tested.
- 5 seasoned and tested.

DOUGLAS FIR.

The material was selected at two western mills. In both cases the test timbers were shipped to the creosoting companies within a few days after they were sawed from logs at the mill, and were treated within a few days after arrival at the creosoting plants. The pieces as selected were 8 inches by 16 inches in section and 32 feet long, and included three grades of material—select, merchantable, and common, as classified by the grading rules of the West Coast Lumber Manufacturers' Association. It is customary to use only select and merchantable timbers in permanent structures. These pieces were cut in two just before treatment, so that the test stringers measured 16 feet. Two processes of treatment were used, the "boiling" process and the "steaming" process. The material which was seasoned before testing was piled in a shed with open sides. The number of 16-foot test stringers used in studying the effect of the two processes, and their condition when treated and tested, was as follows:

Boiling process:
- 20 treated green and tested.
- 20 tested green.
- 19 treated green, seasoned, and tested.
- 19 seasoned and tested.

Steaming process:
- 15 treated green and tested.
- 15 tested green.
- treated green, air seasoned, and tested.
- seasoned and tested.

METHODS OF TREATMENT.

The preservative treatments to which the three species of structural timber were subjected were briefly as follows:

LOBLOLLY PINE.[1]

Steamed for 4 hours under 29 pounds pressure; vacuum of 26 inches applied for 1 hour; cylinder filled with creosote and pressure of 125 pounds applied for 4½ hours at a temperature of 140° F.; vacuum of 23½ inches applied for ¼ hour. Absorption of oil, 13½ pounds per cubic foot of wood.

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[1] Run made Mar. 4, 1908.

LONGLEAF PINE.[1]

Steamed for 6 hours at 30 pounds pressure; vacuum of 26 inches applied for 1 hour; cylinder filled with creosote and pressure of 128 pounds applied for $5\frac{1}{2}$ hours at a temperature of 140° F. Absorption, $12\frac{3}{4}$ pounds per cubic foot of wood.

DOUGLAS FIR.[1]

Boiling process.—Boiled in creosote for $21\frac{3}{4}$ hours at temperature of 215° F.;[2] loss of moisture during boiling, 1.2 pounds per cubic foot of wood; pressure raised from 0 to 145 pounds per square inch in $5\frac{3}{4}$ hours; temperature about 190° F. Absorption of oil, 11.2 pounds per cubic foot of wood, as determined by measuring tank readings.

Steaming process.—Steamed at 90 pounds pressure per square inch for $4\frac{1}{4}$ hours; temperature about 325° F.; vacuum of 20 inches applied for $18\frac{1}{2}$ hours; temperature 220° F. at end of period; cylinder filled with oil and pressure raised from 0 to maximum pressure of 140 pounds per square inch; pressure period, $2\frac{1}{4}$ hours; temperature of the oil, about 208° F. Absorption, 3.1 pounds per cubic foot of wood, as figured from increase in original weight of stringers. The stringers were not weighed after steaming, so that the probable loss can not be taken into account in computing the absorption.

METHOD OF TESTING.

The stringers were tested in bending by supporting them at the ends and applying the load at two points located one-third of the span from each of the end supports. This system corresponds closely to conditions of practice. In testing the beams the load was applied gradually and a record kept of the deflections corresponding to regular load increments. Four factors were calculated from the data derived from each bending test, all in terms of pounds per square inch:

FIBER STRESS AT ELASTIC LIMIT.

This is the greatest stress that can occur in a beam loaded with an external load from which it will recover without permanent deflection.

MODULUS OF RUPTURE.

This is the greatest computed stress in a beam under a breaking load.

MODULUS OF ELASTICITY.

This is a factor computed from the relation between load and deflection within the elastic limit, and represents the stiffness of the wood.

LONGITUDINAL SHEAR.

This is the stress tending to split the beam lengthwise along its neutral plane[3] when under maximum load.

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[1] Run made Mar. 5, 1908.

[2] Some time after the treatments were made it was reported by the treating-plant officials that the thermometer giving this reading registered 40° F. too low.

[3] Plane between upper and lower halves when beam is horizontal.

MOISTURE DETERMINATIONS.

Moisture determinations on the untreated wood were made by taking either borings or disks from the tested pieces, weighing them, and then drying them to constant weight. The difference between the original weight and the dry weight divided by the dry weight times 100 is taken as the per cent of moisture at the time of test. Disks taken from the untreated stringers were cut into a number of pieces and the moisture separately determined for each in order to find the distribution of moisture throughout the cross section. The method of dividing the disks is shown in figure 2. The moisture determinations made on treated specimens were handled by distilling the treated shavings cut from the test pieces with water-saturated xylol. For such determinations a definite quantity of treated borings was taken. In all cases a corresponding volume of untreated shavings was obtained, and the dry weight of this sample determined as a basis for computing the moisture content of the treated sample. All test pieces were weighed and measured, the number of rings counted on a radial line, and the per cent of summerwood and sap determined.[1] Sketches were made and photographs taken, showing the size and location of knots, checks, and shakes.

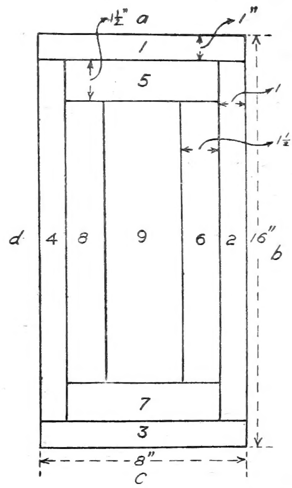

FIG. 2.—Moisture distribution disk for 8-inch by 16-inch stringer.

TESTS ON SMALL STICKS.

After failure occurred in the stringers, small pieces 2 inches by 2 inches in section and 3 feet long were cut from the unbroken portions. These small pieces were selected so as to be free from defects and with straight grain. Their location in a cross section of the stringer was noted, so that data could be secured on the relative strength of the inner and outer portions. The tests of small pieces included bending tests on specimens 2 by 2 by 30 inches, compression tests in which specimens 2 by 2 by 8 inches were crushed endwise parallel with the grain, compression tests at right angles to the grain, and shearing tests in which a projecting portion of a small block was sheared off parallel to the grain while the main portion of the block was held firm.

[1] Determinations of summerwood and sap were omitted for some of the Douglas fir.

RESULTS OF TESTS.

The results of the bending tests on the natural and treated stringers are shown in figures 3 to 7.

The diagrams were made by first plotting the values for modulus of rupture of the natural beams (solid lines) arranged from the highest to lowest, beginning with the highest value on the left at the top of the figure. The modulus of rupture of the treated half (dotted lines) of the test pieces was then plotted in the same vertical line as the untreated pieces. The two values are marked to distinguish butts (*B*) from corresponding tops (*T*). The other values (fiber stress at elastic limit and modulus of elasticity) for the same beams are plotted in the same vertical lines.

Conclusions should not be drawn regarding the comparative effect of creosoting on the strength of the different woods, since they were not treated under similar conditions. It should also be kept in mind that the test material was not selected for the purpose of comparing the various species.

LOBLOLLY PINE.

Figure 3 gives a comparison of the strength and stiffness of natural and treated loblolly pine stringers for partially air-dry and seasoned material. In drawing conclusions from the diagrams it should be kept in mind that butt stringers are naturally stronger than second-cut or top stringers. This point was considered when the method of selecting the test material was determined upon and butts and tops were arranged to alternate in serving as treated and untreated material. It will be noted from figure 3 that when the butts were treated the breaking strength of the butts and tops fell rather close together, while when the tops were treated the breaking strength values were much farther apart. This shows an evident weakening due to the treatment, even when the lower breaking strength of the top stringers is taken into account. The tests are too few to make a definite statement as to the amount of weakening for the specific treatment under consideration. It is probably not more than 17 per cent. The fiber strength at elastic limit and the stiffness both show a greater weakening due to treatment than does the breaking strength. The weakening is more marked in both strength and stiffness in the air dry than in the partially air-dry stringers. Both the treated and untreated stringers showed a strength about 30 per cent greater in the seasoned material than in the partially air-dry material.

LONGLEAF PINE.

In figure 4 the strength of treated and untreated longleaf pine stringers is compared for both partially air-dry and seasoned material. It does not appear that the breaking strength was affected by the treatment used with these stringers. There is a slight reduction in the

average strength at elastic limit and stiffness. In the air-seasoned beams the untreated butt cuts were higher in strength and stiffness than the treated top cuts, but, on the other hand, the untreated top cuts fell below the treated butts in strength and stiffness in nearly every case. In the partially seasoned stringers the treated and untreated material falls together somewhat more closely.

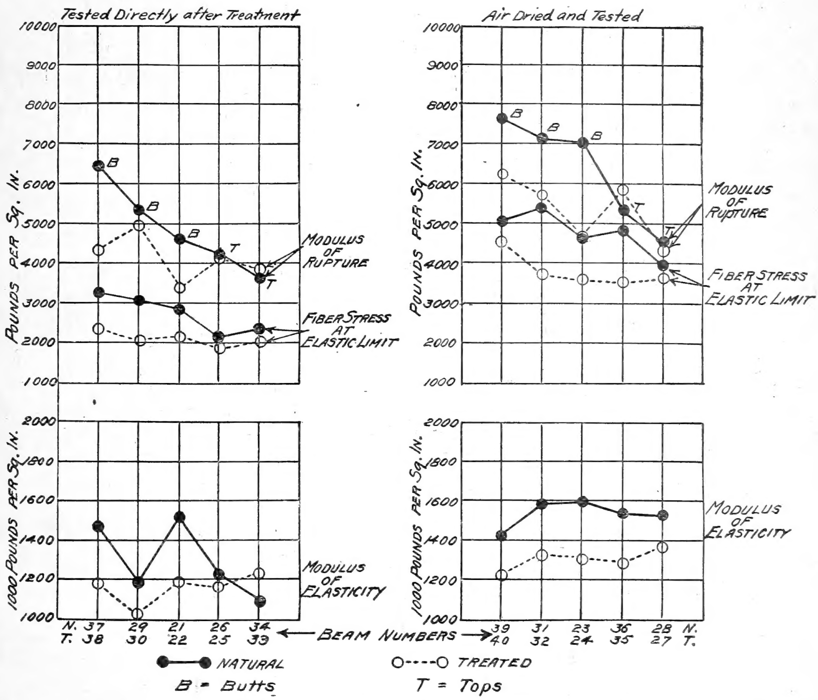

FIG. 3.—Effect of preservative treatment on the strength and stiffness of loblolly-pine stringers treated partially air dry.

DOUGLAS FIR.

Figures 5 and 6 show the strength and stiffness of treated and untreated stringers of green and seasoned Douglas fir, respectively, treated by the so-called "boiling" process as used in this case. There appears to be a marked weakening of the breaking strength with the particular treatment used. The average breaking strength of the stringers tested green and after seasoning is 33 per cent and 39 per cent, respectively, less than the average strength of the natural stringers. The fiber stress at elastic limit also appears to be reduced, although to a somewhat less extent. In the green material no weakening is apparent in the stiffness. The seasoned stringers, however, show a falling off in stiffness in the treated material.

Figure 7 shows the strength and stiffness of green [1] Douglas fir treated by the so-called "steaming" process. The breaking strength

[1] The air-seasoned material is not yet tested, July, 1915.

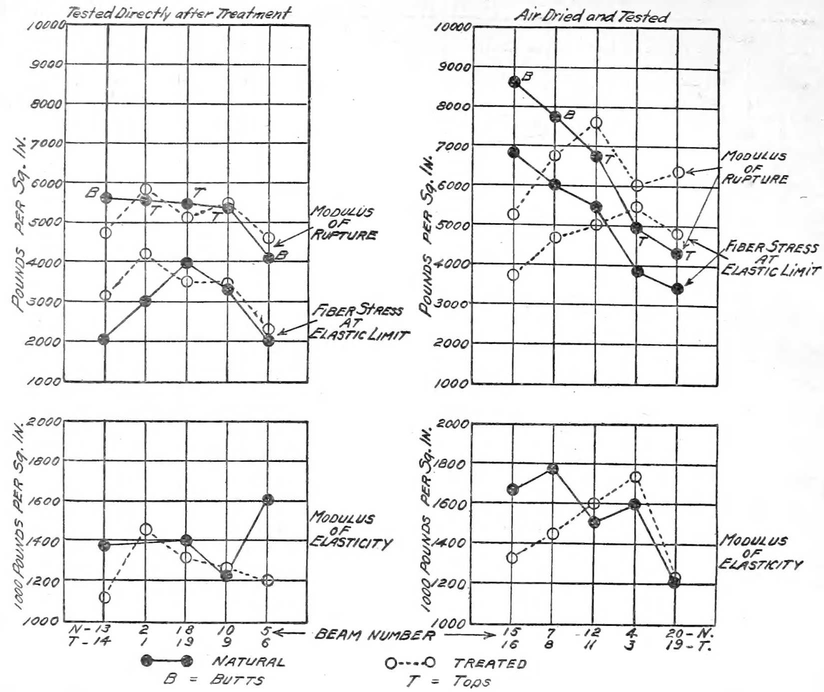

FIG. 4.—Effect of preservative treatment on the strength and stiffness of longleaf-pine stringers treated partially dry.

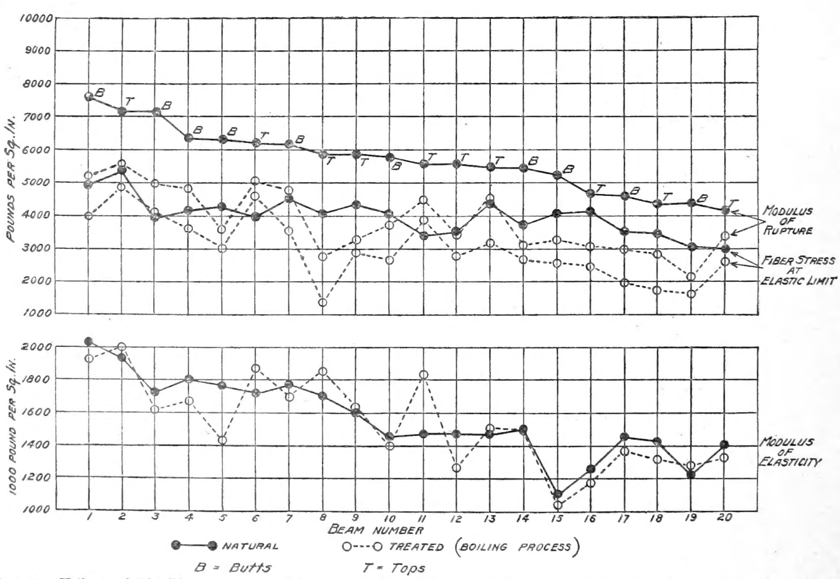

FIG. 5.—Effect of "boiling process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green and tested without seasoning.

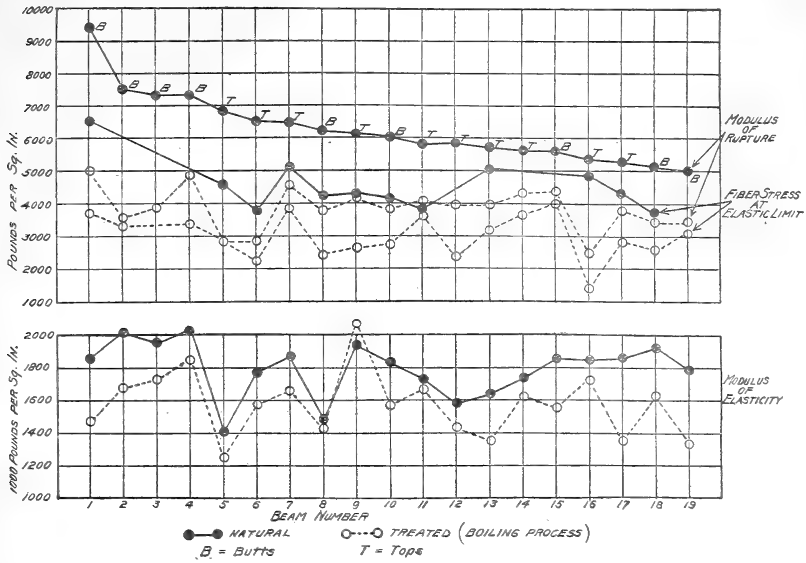

FIG. 6.—Effect of "boiling process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green, air seasoned and tested.

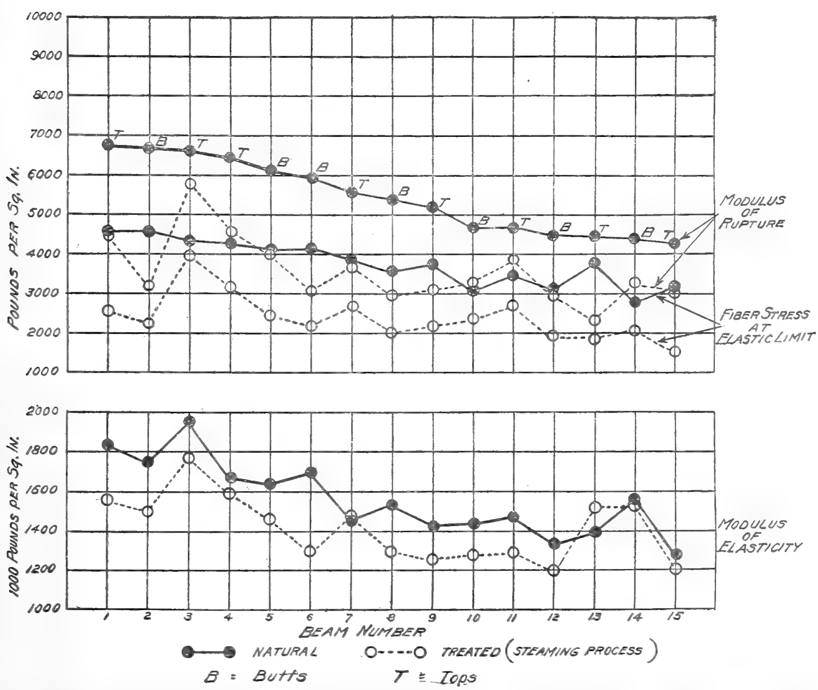

FIG. 7.—Effect of "steaming process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green and tested without seasoning.

TABLE 1.—*Strength and stiffness of natural and treated stringers.*

Species and condition.	Rings per inch.		Summerwood (per cent).		Sap (per cent).		Moisture (per cent).		Modulus of rupture (pounds per square inch).		Modulus of elasticity (1,000 pounds per square inch).		Fiber stress at elastic limit (pounds per square inch).		Shearing stress at maximum load (pounds per square inch).	
	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.
Longleaf pine:																
Partially air dry, 10 tests—																
Average	14.2	14.0	38.8	38.8	5	2	27.6	26.2	5,151	5,132	1,409	1,275	3,346	2,898	408	399
Maximum	17.0	15.5	50.0	51.3	21	11	29.1	30.3	5,575	5,830	1,617	1,462	4,180	3,970	438	452
Minimum	10.8	11.3	28.0	29.3	0	0	25.9	22.1	4,150	4,600	1,235	1,113	2,390	2,050	325	357
Air dry, 10 tests—																
Average	19.2	18.0	38.2	41.6	11	10	19.0	21.8	6,466	6,376	1,561	1,471	4,950	4,762	499	499
Maximum	23.0	19.7	45.3	44.0	21	17	19.6	23.4	8,600	7,620	1,767	1,742	6,040	5,530	658	595
Minimum	17.3	16.3	33.3	38.7	3	2	18.4	21.1	4,280	5,260	1,236	1,227	3,450	3,740	320	408
Loblolly pine:																
Partially air dry, 10 tests—																
Average	5.8	5.9	43.2	43.2	8	14	35.7	49.4	4,858	4,150	1,296	1,155	2,738	2,080	402	339
Maximum	7.3	7.3	52.5	46.0	22	35	54.1	70.2	6,410	4,960	1,515	1,234	3,250	2,340	535	409
Minimum	4.8	4.3	36.8	35.8	0	0	24.1	36.0	3,680	3,390	1,089	1,030	2,160	1,830	301	275
Air dry, 10 tests—																
Average	6.8	7.3	34.5	37.2	40	40	18.2	23.8	6,392	5,380	1,534	1,297	4,806	3,808	507	437
Maximum	10.3	12.3	40.0	45.0	78	70	18.8	29.6	7,680	6,270	1,596	1,367	5,430	4,580	624	509
Minimum	3.7	3.7	33.0	30.3	7	5	17.5	18.7	4,510	4,360	1,430	1,238	3,910	3,520	362	361
Douglas fir:																
Boiling process—																
Green, 40 tests—																
Average	11.0	11.2	45.2	45.4	0	0	33.6	28.5	5,690	3,820	1,569	1,542	3,980	2,980	381	253
Maximum	17.7	19.0	57.0	61.0			38.5	32.8	7,590	5,540	2,070	2,001	5,340	4,850	514	364
Minimum	4.7	5.4	35.0	37.0			28.3	24.3	4,120	2,090	1,115	1,028	2,950	1,370	277	137
Air dry, 38 tests—																
Average	11.5	11.3	39.5	38.2	0	0	15.3	19.5	6,240	3,860	1,809	1,560	4,560	2,840	407	254
Maximum	18.5	19.6	52.0	47.0			17.8	23.0	9,440	4,930	2,402	2,062	6,630	4,010	615	324
Minimum	6.6	6.2	30.0	31.0			13.4	16.4	3,990	2,510	1,400	1,252	3,750	1,360	256	165
Steaming process—																
Green, 30 tests—																
Average	14.7	14.0	36.6	34.2	0	0	37.5	33.0	5,430	3,540	1,557	1,412	3,740	2,370	366	237
Maximum	22.2	20.9	53.8	50.0			45.9	36.8	6,710	5,740	1,945	1,778	4,560	3,930	454	384
Minimum	5.9	5.1	26.3	27.5			32.4	29.3	4,280	2,310	1,277	1,195	2,730	1,490	291	150
Air dry, — tests—																
Average																
Maximum																
Minimum																

and fiber stress at the elastic limit was considerably less in the treated material (35 and 36 per cent, respectively), and the stiffness was slightly less.

Table 1 gives the average values of the strength functions shown in the diagrams, together with the highest and lowest values and some additional data.

SMALL PIECES CUT FROM STRINGERS.

Table 2 gives the average strength and stiffness of the small pieces cut from the main beams for both treated and natural material of the three species under test. The average values of the small pieces cut from the outside portions of the main beams and the average values of the small pieces cut from the interior portions are also given. No moisture determinations were made on the small pieces cut from the treated longleaf and loblolly pine timbers. The determinations for moisture in various parts of the cross sections of the treated timbers of these two species indicate that in general they contained slightly more moisture than the natural pieces. The treated sticks are in general weaker than the natural sticks, but the difference is slight except for partially air-dry loblolly pine. Part of the apparent loss in strength of the treated material may be ascribed to its higher moisture content.

In the Douglas fir treated by the boiling process and tested green, the average for the outside sticks shows a decrease in strength over the natural, with but little difference in stiffness. As compared with the natural sticks the treated sticks cut from the interior of the main beams showed a more marked drop in strength and stiffness. The air-dry material in all cases showed a decided decrease in the strength of the treated sticks. The decrease in stiffness was less marked. Part of this decrease may be accounted for by the higher moisture content of the treated pieces.

TABLE 2.—*Strength and stiffness of small pieces—natural and treated—cut from the inside and outside portions of longleaf pine, loblolly pine, and Douglas fir stringers.*

Species, condition, and locality.	Number of tests.		Moisture (per cent).		Rings per inch.		Modulus of rupture (pounds per square inch).		Fiber stress of elastic limit (pounds per square inch).		Modulus of elasticity (1,000 pounds per square inch).	
	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.
Longleaf pine:												
Partially air dry—												
All	28	29	21.5	......	19.2	18.3	9,507	9,036	5,623	5,365	1,493	1,434
Outside	24	24	21.0	......	19.6	19.3	9,455	9,046	5,587	5,376	1,485	1,428
Inside	4	5	24.6	......	14.6	14.4	9,978	8,870	5,953	5,088	1,581	1,464
Air dry—												
All	23	23	12.8	......	19.9	19.6	13,520	11,418	8,070	6,824	1,663	1,508
Outside	18	17	13.0	......	20.2	18.1	13,109	11,208	8,060	6,855	1,641	1,489
Inside	5	6	12.6	......	18.5	14.2	14,378	11,495	8,153	9,543	1,714	1,527
Loblolly pine:												
Partially air dry—												
All	30	28	20.3	......	6.4	6.4	8,605	6,571	5,109	3,531	1,350	1,104
Outside	24	22	19.8	......	6.9	6.9	8,599	6,221	5,120	3,294	1,339	1,086
Inside	6	6	22.2	......	4.6	5.5	8,592	8,148	5,010	4,560	1,365	1,289
Air dry—												
All	30	26	12.0	......	7.2	7.4	12,491	12,182	7,502	7,611	1,605	1,603
Outside	24	21	12.0	......	7.6	7.6	12,382	12,122	7,434	7,644	1,607	1,609
Inside	6	5	11.8	......	5.7	5.8	13,003	12,157	7,713	7,145	1,595	1,550
Douglas fir:												
Boiling process—												
Green—												
All	48	38	30.1	27.5	10.7	12.6	7,923	6,216	4,450	3,434	1,595	1,486
Outside	24	19	29.6	......	11.7	13.9	8,041	6,862	4,407	3,897	1,617	1,570
Inside	24	19	30.6	......	9.6	11.4	7,805	5,571	4,493	2,971	1,583	1,401
Air dry—												
All	66	54	15.6	......	13.2	13.1	10,608	6,598	6,546	4,003	1,778	1,624
Outside	33	27	14.8	......	14.1	13.6	10,929	6,721	6,953	4,021	1,787	1,617
Inside	33	27	16.4	......	12.2	12.6	10,287	6,475	6,138	3,985	1,770	1,632
Steaming process—												
Green—												
All	....	....	......	......	......	......	....	....	......	......	......	......
Outside	....	....	......	......	......	......	....	....	......	......	......	......
Inside	....	....	......	......	......	......	....	....	......	......	......	......
Air dry—												
All	....	....	......	......	......	......	....	....	......	......	......	......
Outside	....	....	......	......	......	......	....	....	......	......	......	......
Inside	....	....	......	......	......	......	....	....	......	......	......	......

SPECIAL TESTS ON SMALL PIECES.

Table 3 gives a condensed summary of the results of a special series of tests on small clear speciments (2 by 2 inches in section) of Douglas fir, longleaf pine, and shortleaf pine. The tests were made at the Forest Products Laboratory to study the effect of the various steps used in the treatment of the full-sized stringers. Eight sticks were subjected to each of the processes shown in Table 3. One-half of the sticks were tested shortly after treatment and one-half after they had been piled in the laboratory long enough (5 months) to reach a practically constant weight.

All the processes caused a reduction in the strength values of the unseasoned material of the three species with, in most cases, a recovery after seasoning, except in the tension tests. In these the weakening in the unseasoned material remained after seasoning in all processes but the creosote bath.

TABLE 3.—*Effect of various treatments on small clear sticks (results expressed[1] in per cent of strength of untreated material).*

	Steamed at 20 pounds 5 hours.		Steamed at 20 pounds 5 hours; 26-inch vacuum 1 hour.		Steamed at 20 pounds 5 hours; 26-inch vacuum 1 hour; creosote, 120 pounds pressure, 4½ hours.		Creosote at atmospheric pressure, 200° F., 27 hours.		Creosote bath at atmospheric pressure, 200° F., 27 hours; creosote at 145 pounds pressure, 180° F., 1¾ hours.	
	Unseasoned.	Air dry.	Unseasoned.	Air dry.	Unseasoned.	Air dry.	Unseasoned.	Air dry.	Unseasoned.	Air dry.
Bending:										
Modulus of rupture—										
Douglas fir	74	96	78	93	83	86	92	89	86	98
Longleaf pine	83	100	......	......	80	85	......	......	81	93
Shortleaf pine	73	107	72	98	84	104	96	108	89	106
Modulus of elasticity—										
Douglas fir	87	100	84	100	95	98	97	105	93	99
Longleaf pine	94	106	......	......	91	99	......	......	92	108
Shortleaf pine	84	104	92	103	96	105	112	102	96	100
Compression:										
Maximum crushing strength—										
Douglas fir	68	102	76	88	80	97	83	102	90	112
Longleaf pine	79	102	......	......	82	76	......	......	80	87
Shortleaf pine	70	101	71	101	82	104	89	103	89	109
Shear with grain—										
Douglas fir	72	93	74	96	74	100	91	118	86	125
Longleaf pine	77	118	......	......	73	......	......	......	74	115
Shortleaf pine	71	107	74	105	80	108	88	114	90	115
Tension perpendicular to grain—										
Douglas fir	57	69	54	64	48	57	47	116	63	117
Longleaf pine	42	47	......	......	60	......	......	......	61	67
Shortleaf pine	70	81	71	73	71	64	95	130	79	88
Shrinkage[1] in cross section during treatment—										
Douglas fir	.13	......	.83	......	3.34	......	.73	......	9.33	......
Longleaf pine	.42	......	......	......	.08	......	......	......	.66	......
Shortleaf pine	.33	......	.50	......	.92	......	[2].25	......	.75	......
During treatment and seasoning—										
Douglas fir	......	8.58	......	8.35	......	7.39	......	7.46	......	11.31
Longleaf pine	......	10.64	......	......	......	6.18	......	......	......	7.90
Shortleaf pine	......	10.47	......	9.30	......	5.94	......	7.50	......	5.73

[1] Shrinkage given in per cents of areas when first measured. Corresponding shrinkage of untreated material: Douglas fir, 6.40; longleaf pine, 8.48; shortleaf pine, 7.29.
[2] Increase in volume.

The shrinkage measurements on the steamed material with and without vacuum showed less than 1 per cent decrease in volume during treatment for all the species. After seasoning a shrinkage of from 8.4 per cent for Douglas fir to 10.6 per cent for longleaf pine was recorded. Steaming and vacuum followed by creosote showed a somewhat higher shrinkage for Douglas fir than for the pines, both in the unseasoned and air-dry pieces. The creasote bath had little influence on the shrinkage, the reduction after seasoning corresponding closely to the shrinkage of untreated pieces. The pressure treatment following the creosote bath showed a somewhat higher shrinkage for Douglas fir than for longleaf or shortleaf.

While the weakening in the Douglas fir stringers is not explained by the series of special tests, they indicate that the trouble has to do with stresses in the full-sized stringers, probably caused by rapid and unequal shrinkage during the process. A further series of tests is now under way on 8-foot stringers 8 by 16 inches in section treated at the Forest Products Laboratory, from which results that bear more directly on the problem are expected.

DEDUCTIONS.

(1) Timber may be very materially weakened by preservative processes.

(2) Creosote in itself aoes not appear to weaken timber.

(3) A preservative process which will seriously injure one timber may have little or no effect on the strength of another.

(4) A comparison of the effect of a preservative process on the strength of different species should not be made, unless it is the common or best adapted process for all the species compared.

(5) The same treatment given to a timber of a particular species may have a different effect upon different pieces of that species, depending upon the form of the timber used, its size, and its condition when treated.

PUBLICATIONS RELATING TO STRENGTH TESTS OF VARIOUS WOODS.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

Fire-killed Douglas Fir: A Study of Its Rate of Deterioration, Usability, and Strength. By Joseph Burke Knapp. Pp. 18, figs. 5. 1912. (Forest Service Bulletin 112.)
Mechanical Properties of Western Larch. By O. P. M. Goss. Pp. 45, Pls. IV, figs 14. 1913. (Forest Service Bulletin 122.)
Experiments on the Strength of Treated Timber. By W. Kendrick Hatt, Ph. D. Pp. 31, figs. 2, tables 12. 1906. (Forest Service Circular 39.)
Tests of Rocky Mountain Wood for Telephone Poles. By Norman de W. Betts and A. L. Heim. Pp. 28, figs. 6, tables 7. 1914. (Department Bulletin 67.)
Rocky Mountain Mine Timbers. By Norman de W. Betts. Pp. 34, figs. 7, tables 16. 1914. (Department Bulletin 77.)
Tests of Wooden Barrels. By J. A. Newlin. Pp. 12, figs. 1, Pls. V, tables 6. 1914. (Department Bulletin 86.)

PUBLICATIONS FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

Timber: An Elementary Discussion of the Characteristics and Properties of Wood. By Filbert Roth and B. E. Fernow. Pp. 88, figs. 49. 1895. (Forest Service Bulletin 10.) Price, 10 cents.
Effect of Moisture upon the Strength and Stiffness of Wood. By Harry Donald Tiemann, M. E. M. F. Pp. 144, figs. 25, Pls. IV. 1906. (Forest Service Bulletin 70.) Price 15 cents.
Properties and Uses of Douglas Fir: Part I, Mechanical Properties. Part II, Commercial Uses. By McGarvey Cline and J. B. Knapp. Pp. 75, Pls. III, diagrams 15. 1911. (Forest Service Bulletin 88.) Price 15 cents.
Tests of Structural Timbers. By McGarvey Cline and A. L. Heim. Pp. 123, Pls. VII, text figures 29. 1912. (Forest Service Bulletin 108.) Price 20 cents.
Mechanical Properties of Western Hemlock. By O. P. M. Goss. Pp. 45, figs. 13, Pls. VI. 1913. (Forest Service Bulletin 115.) Price 15 cents.
Holding Force of Railroad Spikes in Wooden Ties. By W. Kendrick Hatt, Ph. D. Pp. 5, figs. 4. 1906. (Forest Service Circular 46.) Price 5 cents.
Tests of Vehicle and Implement Woods. By H. B. Holroyd and H. S. Betts. Pp. 29, tables 8. 1908. (Forest Service Circular 142.) Price 5 cents.
Properties and Uses of the Southern Pines. By H. S. Betts. Pp. 30, figs. 6, 1909. (Forest Service Circular 164.) Price 5 cents.
Utilization of California Eucalypts. By H. S. Betts and C. Stowell Smith. Pp. 30, figs. 7. 1910. (Forest Service Circular 179.) Price 5 cents.
Strength Values for Structural Timbers. By McGarvey Cline. Pp. 8, tables 4. 1912. (Forest Service Circular 189.) Price 5 cents.
Mechanical Properties of Redwood. By A. L. Heim. Pp. 32, figs. 8, tables 7. 1912. (Forest Service Circular 193.) Price 5 cents.
Mechanical Properties of Woods Grown in the United States. Pp. 4, table 1. 1913. (Forest Service Circular 213.) Price 5 cents.
Tests of Packing Boxes of Various Forms. By John A. Newlin. Pp. 23, figs. 4, tables 6. 1913. (Forest Service Circular 214.) Price 5 cents.

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